Approach for improve plant (*Pisum sativum* L.) growth and yield using kiln coal fly ash amended soil

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Abstract: Fly ash originated from coal based brick kiln, thermal power plants and many other industries which create environmental problems due to unfair utilization and disposal. Regular use of chemical fertilizers is known to enhance crop productivity, but also degrading soil quality both physically and chemically. The present investigation was conducted to find out the impact of different levels (25 gm, 50 gm, and 100 gm per meter^2) of fly ash on the determination of morpho-physiological properties of soil and plant such as pH, cation exchange capacity, bulk density, particle density, porosity of soil, germination of seed, plant height (root+shoot), nodulation (Number, weight, volume), biomass production of *Pisium sativum.* All these were found to be favourably affected by fly ash induced changes in morpho-physiological properties of soil and plant. The experiments were conducted in field during 2017-2018 with *Pisum sativum* L. (Pea) grown with fly ash amended soil at department of Botany C.C.S. University, campus, Meerut (U.P.) India. Hence, through the present research work one can conclude that fly ash in optimize amount (25gm/m^2) can be a mileage for sustainable agriculture.

Keywords: Crop productivity, Fly ash, fertilizers, optimize amount, *Pisum sativum* L.

INTRODUCTION

Pulses have been important source of protein, vitamins, minerals, starch, oil, and health protecting compounds from the start up of human history. The family Fabaceae is one of the enormous families of flowering plants with more than19500 species and 732-765 genera (Roskov *et al.,* 2017; Lewis *et al.,* 2005). Well known symbiotic relationship between pulses and root-nodule bacteria (*Rhizobium*) fulfillment the biological nitrogen fixation for natural and agro-ecosystems around the globe (Crews *et al.,* 1993). Biological nitrogen fixation which may be considered the great fundamentally important in biological procedure on earth aside from photosynthesis (Howieson *et al.,* 2008; Schlautman *et al.,* 2018). The ecological and economic importance of pulses is proved by the large number of species that are cultivated and commercialized as well as by their ability to fix atmospheric nitrogen by the symbiotic relationship with *Rhizobium* Clua *et al.,* (2017).

Pea is an important food crop for human as food (Olle *et al.,* 2015). It seeds are rich in protein (23–25 %), slowly digestible starch (50%), soluble sugars (5%), fibers, minerals and vitamins (Georgieva 2016; Smykal, 2012). It seeds have a high nutritive value, particularly proteins and other health building substances, such as carbohydrates, vitamin A, vitamin C, calcium and phosphorus (Sharma *et al* ,2013). It also contains a variety of phytochemicals including phenolic compounds, phytates, saponins and oxalates. The major phenolic constituents in pulses are tannins, phenolic acids and flavonoids (Campos-Vega *et al.,* 2010). The origin of *Pisum* spp. is in Southwestern Asia including Afghanistan, India, Pakistan, and then spreads to subtropic and tropic regions (Majeed *et al*., 2012). *Pisum sativum* is an herbaceous annual, with a climbing hollow stem, leaves are alternate, pinnately compound, and consist of 2–3 pairs of 1.5–8 cm long large leaf-like stipules. The pod is a seed container which composed by two sealed valves and splitted along the seam which connects the two valves. Seeds are round, smooth, and green color (Pavek *et al.,* 2012).

The high amounts of inorganic fertilizers have been implicated with soil acidification, organic carbon loss, imbalance of nutrients and micro and macro nutrients deficiency. So many studies proved that kiln fly ash can be used as a soil conditioner that may enhance the biological, physical, chemical properties of the degraded soils (Kumar and Kumar 2016, 2017).

Increased urbanization and industrialization worldwide has resulted in increased releases of solid waste, and enhanced environmental pollution around the globe (Singh *et al.,* 2011). Coal based brick kiln and thermal power plants generated fly ash as industrial waste product, approximately 70-75% (Belyaeva and Haynes, 2012) and it has been recognized as an environmental hazard across the globe. It is a mixture of ferro-alumino-silicates material with Fe, Al, Na, Ca and Si as the pre-dominant elements (Tripathi *et al*., 2013). It has a low bulk density, high surface area and light texture (Sawitri and Lasryza, 2012). Instead of dumping as a waste material, the utilization of fly ash can be both economically valuable and environment friendly (Mohan *et al.,* 2012). Fly ash is a potential source of many macro and micro elements to the plant including some toxic metals (Mehra, 1986). Focused on its potential as a fertilizer to supply nutrients such as B, Mo, P, K, S, Ca, Cu, Mg, and Zn (Gaind *et al.,* 2002). Singh and Pandey (2013) are reported that the application of fly ash, compost and press mud or a combination there of, improves plant growth, soil microbial communities, soil physico-chemical characteristics etc.

Fly ash could be supplemented in enhancing plant growth and soil quality at a limited amount. But if it used in excess amount it could results vice versa (Sudarshana Sharma, 2016). An application of fly ash in agricultural sector helps in the saving of chemical fertilizers. Many crops of the families Leguminoceae, Poaceae, Brassicaceae and Chenopodiaceae are most tolerant to fly ash (Cheung, 2000). Low amount of fly ash can be a good additive for neutralizing the soil acidity and can also use as a source of fertilizer. Fly ash has although been identified as pollutant and fertilizer both, but the earlier work done was confined to some physico-chemical attributes of Pea and soil. Present work is aimed at exploring the fertilizer potential of fly ash in terms of soil conditioner.

MATERIAL AND METHODS

Experimental site: This field research work was conducted during the Rabi season in the month of November to January during 2017-2018 to evaluate the response of fly ash on the Physio-Chemical property of soil and growth and development of *Pisum sativum* L. The seeds of *Pisum sativum* L. were grown in the field of Botany department C.C.S. University campus, Meerut (U.P.) India. The experiment designed in four plots of equal size ($1 \times 1 meter^2$), three plots for the treatment and one plot for the control. Three samples of different concentrations of fly ash were prepared such as 25 gm, 50 gm, and 100 gm per $meter^2$. First plot was untreated or control and the remaining three plots were designed for 25gm, 50gm and 100gm fly ash treatments.

Material used:

1. Certified seeds of *Pisum sativum* L. (Pusa pargati) were collected from IARI, New Delhi.
2. Fly ash was collected from the brick kiln at the town Hastinapur Meerut U.P. India.

Recorded parameters:
pH: pH of soil was measured by the method of A.K. Covington (2009).

Cation exchange capacity: CEC of soil was measured by the method as adopted by Jones (1967).

Moisture content: Moisture content of the soil was measured by using the method adopted by Reeb (1999).

Seed Germination Assay: Seed Germination Assay was counted by ISTA (1976):

Bulk Density of Soil: Soil bulk density was determined by the method of Cresswell and Hamilton (2002)

Yield Parameter, nodulation, and biomass: Yield parameter, nodulation, and biomass were measured by Rajpoot *et al.*, **(**2018).

Bulk Density of Soil: Soil bulk density was determined by the method of Cresswell and Hamilton (2002).

Porosity of soil: The porosity of soil was measured by Piper (1966) method.

RESULT AND DISCUSSION

pH of soil: Measured pH of fly ash was highly acidic (2.80) and pH of soil was alkaline (8.08). Maximum pH (acidic) of soil was observed in the case of 100 gm/m^2 fly ash treated soil in comparison to control and other fly ash treated soils (Table -1). Siddharth *et al.* (2011) and Nivetha *et al.* (2017) also found the liming potential of fly ash. CaO and MgO are the major constituents of fly ash. These basic oxides of fly ash those react with water in the presence of CO_2 form hydroxyl ions and carbonate precipitate which increases the soil pH. Fly ash increases the soil pH, texture and also helps in agronomic benefits (Phung *et al.*, 1979). Similar kinds of results have been reported earlier by Saxena and Asokan, (1998).

Bulk density and particle density of the soil: Applications of 25, 50 and100 gm/m^2 reduces the bulk and particle density of soil (Table-2). Bulk density and particle density of the soil has a stable negative correlation with fly ash (Saxena and asokan, 1998). It may be the reason that the Ca elements of fly ash readily replaces Na elements at soil exchange site and thereby enhances the flocculation of soil particles (Sahu *et al.*, 2017).Similar kinds of results have also been reported earlier by Mishra *et al.*(2017).

Porosity of soil: Porosity of a soil sample is it's that volume which is occupied by air and water or it is also defined as the fraction of soil volume not occupied by soil particles. Gradual increases in fly ash concentrations from 25 to 100 gm/m^2 decrease the soil porosity (Table-3). It may be due to the increasing amount of fly ash increases the solid particles percentage in soil which increases the soil porosity (korcak *et al.*, 1995). Similar kinds of results have been reported earlier by Mishra *et al.* (2017).

Cation exchange capacity: Cations are positively charged ions like Ca^{2+}, Mg^{2+}, K^+, Na^+, H^+, Al^{3+}, Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+}. The efficiency of the soil to catch on to these cations called the cation exchange capacity (CEC). The maximum CEC of soil was observed in untreated soil while minimum in 100 gm/m^2 fly ash treated soil (Table-4). The relationship of fly ash and CEC of soil is inversely proportion. Applications of fly ash improve the soil conditions by increasing the cation exchange capacity of soil, which may result in the immobilization of toxic metals and increase the uptake level of Ca^{2+}, Mg^{2+}, K^+, Na^+, H^+, Al^{3+}, Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+} by roots (Sharma *et al.* 2012). Similar findings also have been reported by Pandey *et al.* (2009).

Germination: The seed germination % gradually decreases from untreated to treated soils in starting 7 and 14 days of sowing while increases in 21 days of after sowing of seeds. Overall the maximum germination % was observed in 25 gm fly ash treated plots (at 21 days) as compare to control and other (50gm, 100gm) fly ash treated plots(Table-5). It may be due to the presence of plant nutrients in fly ash such as K, Mg, S and micronutrients, plants use fly ash as a source of important plant supplements, which enhances the germination % of the seeds. In present study we observed that the fly ash treatment was beneficial for germination of *Vigna radiata* seeds up to 25gm/ m^2. However, the higher concentrations of fly ash (50 and 100 gm/ m^2) had deleterious effect. Katiyar *et al*. (2012) and Panda (2015) were also found such similar kinds of result.

Plant Height: The maximum plant height including both root and shoot length was significantly increased in 25 gm/m^2 fly ash treated plots as compared to untreated and other fly ash treated plots (Table-6) . This may be due to the availability of micro and macro nutrients present in the brick kiln coal fly ash. Rizvi *et al.* (2009) were also found similar kinds of results in his investigation. They observed that the application of brick kiln dust at lower levels has beneficial for the plants growth and yield. Raj *et al.* (2016) also found the presence of heavy metals in fly ash, plant growth and height enhances because of plants use these metals as a fertilizer from the fly ash treated soil. But high amount of fly ash inhibits the plant growth due to the toxicity of heavy metals.

Yield Parameter: The maximum number of pods per plant was counted in 25 gm/m^2 fly ash treated plot as compared to control and other fly ash treated plots. However, number of seeds per pod was counted maximum in the control as compare to other treated plots (Table-7). This may be due to the presence of heavy metals in fly ash used by the plants as a nutrient/supplement. The presence of heavy metals in fly ash, plants has used as a fertilizer but higher amount of fly ash have toxic effects on the plants metabolic pathways. Faizan and Kausar (2010); Singh *et al.* (2011) also were found same results in his experimental works on *Pisum sativum*. Raj *et al.*, 2016 were also suggested the same results. Fly ash has been applicable to enhance the productivity of some agricultural crops and leguminous plants like *Vigna radiata, Vigna mungo etc*. (Kumar *et al.*, 2002).

Nodulation: The maximum nodule attributing characters such as number, weight, volume was observed in 25 gm/m^2 fly ash treated plots as compared to control and other 50 and 100 gm fly ash treated plots (Table-8). Faizan *et al.* (2010) were also reported, that the 25% fly ash application causes a positive effects on number and weight of the nodules. Better nodulation at 25% treatment plants due to the availability of micronutrients which are necessary for enhancing the many physiological processes of the plant. So, Brick kiln coal fly ash is preferred (in low concentration) for the maximum productivity of the plants. Root infection by *Rhizobium* enhances the nodulation which leads to higher rate of biological nitrogen fixation (Singh, 1996). Lal and Khanna (1994) also reported the reduced symbiotic activity of nodules with increasing dose of ash fly.

Biomass of plant: Plant biomass is a renewable energy source that is produced through photosynthesis. The maximum plant biomass was observed in 25 gm/m^2 fly ash treated plot and minimum in 100 gm/m^2 fly ash treated plots as compare to untreated and 50 gm/m^2 fly ash treated plots (Table-9). Similar results were also found by Faizan and Khan, (2004). They observed that the plant biomass and yield exhibit their maximum result at 25% coal ash amended soil and depressive effect of heavy metals in coal fly ash is directly related to reduce in biomass, length and yield of plants. All these parameters were decreased due to the presence of high amount of heavy metal in coal fly ash. Increased mineral nutrients level in the plant would not only benefit but would also lead to increased photosynthesis which increases the biomass production. However, higher amount of mineral nutrient also inhibit and disrupt the metabolic activities which is harmful to a plant. So that higher amount of fly ash reduces the plant biomass.

Conclusion: Based on the experiment, it can be adduced that there is an ample scope for the secure utilization of brick kiln coal fly ash in agriculture without serious harmful effects. Impact of fly ash to soil has been found to enhance the bioavailability of heavy metals, and its low doses (25gm/m^2) did not cause deleterious effects. Significant increases in heavy metal concentration and could be used as soil fertilizer. The present study was conducted stimulating impact of fly ash on growth parameters of *Pisum sativum* such as germination of seed, yield parameter; nodulation attributes plant height and biomass production of *Pisum sativum*. Bulk density, particle density, porosity, cation exchange capacity, and pH of soil. After analyzing all the results of experiment it was demonstrated that impact of fly ash to a sufficient amount results in an increase of availability of macro and micronutrient of the soil. Fly ash acts as an excellent classic soil modifier conditioner and a source of essential plant nutrients for laudably improving the texture and fertility of the soil with significant increases in crop yield over the untreated. At the same time it will be safe and eco-friendly disposal option for huge amount of fly ash.

Tables:

Table1: Effect of fly ash application on pH of soil.

S.N.	Treatments	pH of soil
1	Fly ash	2.70
2	Untreated	8.08
3	25 gm fly ash/m^2	7.56
4	50 gm fly ash/m^2	7.36
5	100 gm fly ash/m^2	7.29

Table2: Effect of fly ash application on bulk density of soil and particle density of soil.

S.N.	Treatments	Bulk density of soil	Particle density of soil
1	Untreated	1.61	2.59
2	25 gm fly ash/m^2	1.58	2.49
3	50 gm fly ash/m^2	1.57	2.47

4	100 gm fly ash/m^2	1.57	2.45

Table3: Effect of fly ash application on Porosity of soil (%) of soil.

S.N.	Treatments	Porosity of soil (%)
1	Untreated	37.70
2	25 gm fly ash/m^2	36.70
3	50 gm fly ash/m^2	36.30
4	100 gm fly ash/m^2	35.80

Table 4: Effect of fly ash application on cation exchange capacity of soil.

S.N.	Treatments	CEC
1	Untreated	11.00
2	25 gm fly ash/m^2	10.60
3	50 gm fly ash/m^2	10.80
4	100 gm fly ash/m^2	09.24

Table 5: Effect of fly ash application on germination % of *Pisum sativum* L.

S.N.	Treatments	Germination percentage (%)		
		7 day (After sown)	14 day (After sown)	21 day(After sown)
1	Untreated	36	38	43
2	25 gm fly ash/m^2	28	32	46
3	50 gm fly ash/m^2	28	31	45
4	100 gm fly ash/m^2	30	30	44

Table 6: Effect of fly ash application on plant height (cm) of *Pisum sativum* L.

S.N	Kinds of fly ash treatment	Root length	Shoot length	Total length
1	Untreated	15.26	37.40	52.66
2	25 gm fly ash/m^2	17.10	40.26	57.36
3	50 gm fly ash/m^2	15.20	33.90	49.19
4	100 gm fly ash/m^2	14.80	33.10	47.90

Table 7: Effect of fly ash application on yield parameters of *Pisum sativum* L.

S.N.	Treatments	Number of pod/ plant	Number of seed/pod
1	Untreated	23	10
2	25gm/m^2 fly ash	24	07
3	50gm/m^2 fly ash	23	07
4	100gm/m^2 fly ash	22	07

Table 8: Effect of fly ash application on nodulation parameters of *Pisum sativum* L.

S.N.	Treatments	Weight of Nodule (g.)	Volume of Nodule(ml)	Number of Nodule
1	Untreated	0.851	0.704	53
2	25gm/m^2 fly ash	1.371	0.726	66
3	50gm/m^2 fly ash	0.692	0.708	50
4	100gm/m^2 fly ash	0.588	0.654	44

Table 9: Effect of fly ash application on nodulation parameters of *Pisum sativum* L.

S.N.	Treatments	Fresh weight of root	Dry weight of root	Fresh weight of shoot	Dry weight of Shoot
1	Untreated	2.60	0.20	7.11	1.36
2	25gm/m^2 fly ash	3.44	0.28	7.05	1.34
3	50gm/m^2 fly ash	3.41	0.27	6.05	1.29
4	100gm/m^2 fly ash	2.79	0.19	6.01	1.01

Acknowledgment: Authors like to give their thanks to Dept. of Botany, Chodhary Charan Singh University, Meerut to providing necessary facilities to complete this study.

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